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The aquatic insects of Mill Creek, California

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THE AQUATIC INSECTS OF MILL CREEK, CALIFORNIA

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INTRODUCTION

The study of insects has been a hobby for me for more than twenty years. Their diversity and adaptation to many habitats has been of particular interest. Ever since the removal of my first aquatic nymph from the crashing waters of the American River, I have been especially fascinated with these insects. Since I had access to a relatively undisturbed year round stream, I chose to study the aquatic insects of this stream. The purpose of this study was to survey the aquatic insect fauna of Mill Creek during the course of a year and relate these findings to the River Continuum Concept.

In 1980, Robin Vannote and associates proposed the River Continuum Concept (Vannote et al, 1980). This concept states that streams are composed of a continuous gradient of physical variables and that living communities are established in equilibrium with these physical variables. The variables include width, depth, velocity, flow volume, temperature and entropy gain which are coupled with the hydrologic cycle, resulting in consistent patterns of community structure and function. These communities develop processing strategies that involve minimal energy loss and the downstream communities capitalize on upstream inefficiencies (Vannote et al, 1980).

Streams are divided into orders primarily based upon number and types of water inputs. They are numbered from one to twelve and represent a continuum along the stream's length. Stream orders are generally grouped to represent three major portions of a stream (Cummins, 1975).

Orders one through three are small headwaters which are dominated by their terrestrial surroundings. They are heterotrophic with energy input coming primarily from surrounding land plants in the form of coarse particulate organic matter (CPOM). These streams are light- and nutrient-poor which results in a ratio of photosynthetic rate to respiration rate (P/R) of less than one. Coarse sediment dominates the stream bed and water temperature does not fluctuate greatly throughout the year. The CPOM is reduced to fine particulate organic matter (FPOM) by fungi and shredders and made available to other stream invertebrates. These orders have been described as "CPOM-fungi-shredder-FPOM-bacteria-collector" systems (Cummins, 1975).

Orders four through six are medium-sized streams that are autotrophic and less dependent upon the terrestrial surroundings for energy input. They are light- and nutrient-rich with the P/R ratio greater than one. Water temperature fluctuates widely and the stream bed has much sediment. These orders have been described as "producer-grazer-FPOM-bacteria-collector" systems (Cummins, 1975).

Orders seven through twelve are large rivers that are heterotrophic, often carrying a heavy organic and sediment load. They are light-poor and nutrient-rich with the P/R ratio less than one. Water temperature fluctuates little and the stream bed is dominated by fine sediment. These orders have been described as "FPOM-bacteria-collector" systems (Cummins 1975).

A diagramatic representation of this paradigm is presented in Figure 1.

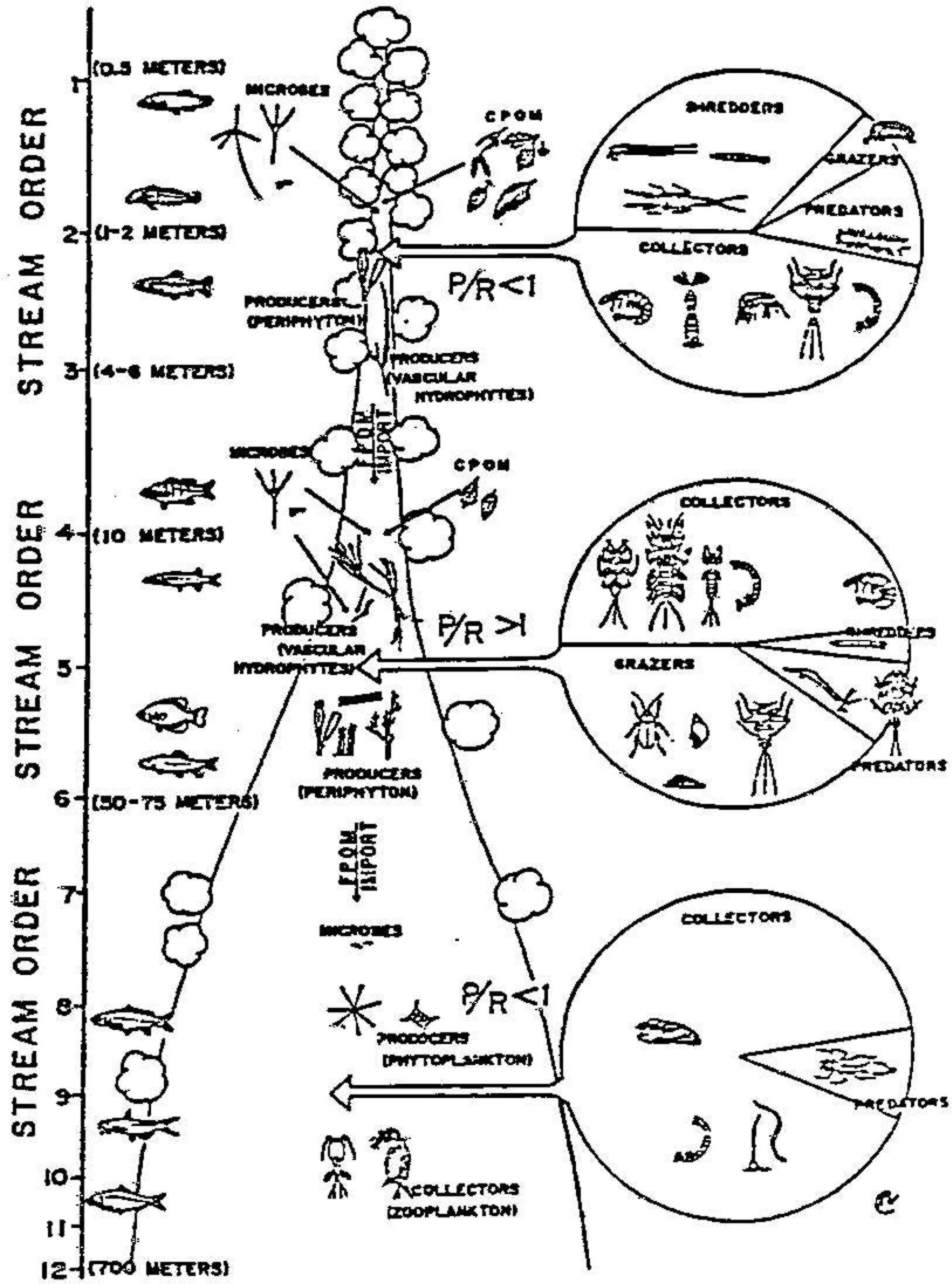

Figure 1. Diagramatic representation of certain changes in structure and function in running water ecosystems (Cummins, 1975).

STUDY SITE

Mill Creek lies within Township 7N., Range 13E., of the West Point Quadrangle map of California. It is located at 3000 feet in the Mokelumne River drainage basin in the Sierra Nevada mountains. Mill Creek passes through privately owned land and access to the stream requires permission from the owners. There appears to be little human disturbance of the stream and owner use is infrequent.

Flow varies from medium to fast. Stream bed width varies from three to eight meters with a year round channel of one to two meters. Deeper holes are scattered along the stream. Some holes are one meter deep and several meters long. Water depth fluctuates from a few centimeters during the late summer and fall to periods of more than two meters after heavy rain. Water flow has been uninterrupted during the last ten years. The stream bed is covered by cobbles ranging in size from 10-30 cm in diameter with occasional, large boulders found buried in the stream bed. Trapped below and between the cobbles is gravel, sand and some fine sediment.

The stream is situated within a relatively steep V-shaped canyon which receives varying amounts of sunlight throughout the day. Trees growing on the canyon walls add to the shading of the stream. Conifers occurring in this area include white fir (Abies concolor), Douglas fir (Pseudotsuga menziesii), incense cedar (Calocedrus decurrens), and ponderosa pine (Pinus ponderosa). Deciduous trees occurring in this region include black oak (Quercus kelloggii), white alder (Alnus rhombifolia), and madrone (Arbutus menziesii).

Figure 2 shows the location of the four collecting stations used in this study. These stations were selected for their different characteristics which might result in different benthic communities.

Station A (Figures 3 and 4) was the collecting site farthest downstream. The stream bed was approximately eight meters wide with water depth ranging from a few to 70 cm. The sediment was gravel and some sand interspersed among small to large cobbles. There was a narrow, year-round channel along one bank with a broad shallow area along the other bank. This shallow area was covered with water during rainy periods and dry during low water periods. Sunshine and shade alternated throughout the day. Sampling was done along a 25 m section of this station. Most samples were collected from the deeper channel but some samples were collected from the shallow areas when water conditions permitted.

Station B (Figures 5 and 6) was approximately 250 m upstream from Station A. The stream bed was about four meters wide and water depth was from a few to 60 cm. The sediment was gravel and sand interspersed among small to

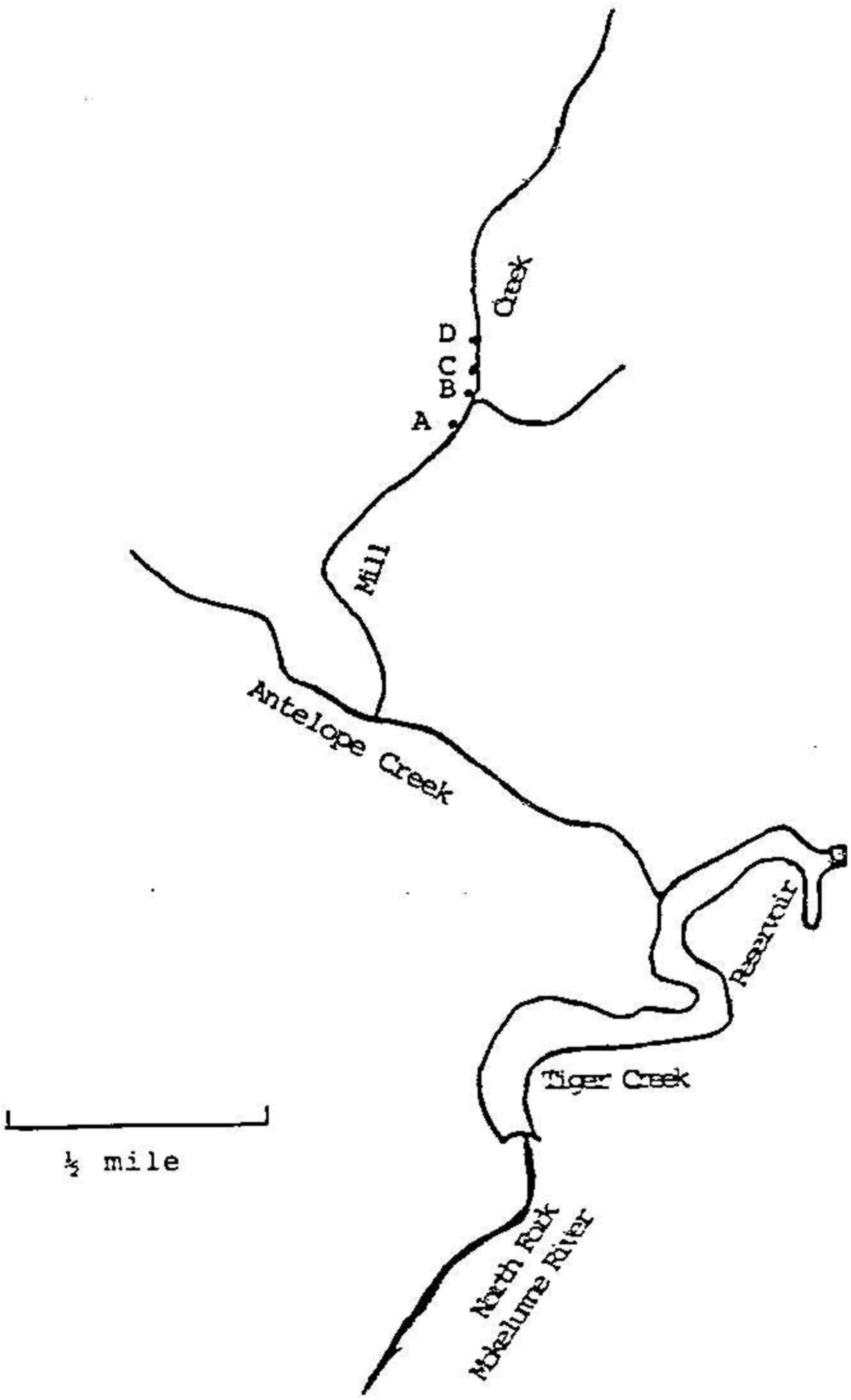

Figure 2. Location of sampling stations on Mill Creek, Amador County, California.

large cobbles. Some deeper holes occur in the lower end of this station. This station is well shaded due to the large trees at the edge of the stream and the steeply sloped canyon walls. Collecting was done along a 25 m section of this station.

Station C (Figures 7 and 8) was about 200 m upstream from Station B. The stream bed was approximately four to seven meters wide and the water depth was from a few to 30 cm. The sediment was fine sand and gravel interspersed among medium sized cobbles. One bank was caved-in supplying fine sediment to the stream. The most downstream portion had a series of step-like falls. This station was well lighted due to the absence of large trees close to the stream. Collecting was done along a 20 m section of this station. During the spring and summer of 1983 the owners of this property rechanneled the stream to an area about eight meters to the east of the old channel. As a result the stream bed was now approximately two meters wide and water depth was 50 cm. This diversion resulted in the step-like falls becoming dry.

Station D (Figures 9 and 10) was approximately 400 m upstream from Station C. It had a large pool (about seven meters in diameter) at its beginning. This pool was created by water gouging out the stream bed as it spilled from a large metal culvert. The stream bed was approximately three to five meters wide and the water depth was from a few to fifty cm. The sediment was coarse gravel interspersed among small to large cobbles. Very little sand or fine sediment was present. This station received abundant sunlight as surrounding trees were set back from the stream bed. One side of the stream had a large accumulation of woody debris behind a large log. Sampling was done along a 20 m section of this station. No samples were taken from the pool.

Figure 3. Station A, looking downstream showing the contrasting light conditions.

Figure 4. Station A, showing the shallows which alternated between being wet and dry.

Figure 5. Station B, showing the deep shade of this station.

Figure 6. Station B, showing a deep hole with some large boulders.

Figure 7. Looking upstream at Station C. The lower right corner was the beginning of the step-like falls.

Figure 8. Station C, left edge shows where the bank was caving into the stream.

Figure 9. Station D, looking upstream showing the log and wood debris.

Figure 10. Station D, showing the pool edge where collecting began.

MATERIALS AND METHODS

Collections were made monthly for one year, (December 1981 to December 1982). No collection was possible during January due to heavy snow, ice and rain. Similarly, the September collection was postponed until early October because of heavy rain.

Adult collections were made with a sweep net during the day. A lighted, white sheet was used at dusk throughout the late spring and summer months to attract adult insects.

Larvae were collected using a Needham net (a wire screen approximately one meter square with mesh size approximately 2.0 mm^2). The screen was placed between cobbles or below a debris dam and the upstream substrate was disturbed with a four-pronged, metal garden rake. The stream current washed the larvae onto the screen. All specimens were removed and placed into 70% isopropyl alcohol. They were later sorted to orders and eventually identified to their respective genera using appropriate keys (i.e., Edmunds et al, 1976; Merritt and Cummins, 1979, 1984; Stark and Gaufin, 1976; Wiggins, 1978; Usinger, 1956). Quantitative sampling was not attempted. Six to eight screenings were made at each station. Qualitative sampling was maximized by screening in a wide variety of habitats: in debris dams, in the deeper year-round channel as well as the temporary shallows, from the side and mid-stream regions, and under large and small cobbles.

The specimens collected are deposited in the entomological collection of the Department of Biological Sciences in the University of the Pacific.

RESULTS

In this study, specimens from eight of the twelve aquatic insect orders were collected. The most abundantly represented of these orders were Ephemeroptera, Plecoptera, Trichoptera, Diptera and Coleoptera. Seventy-five per cent of the 2,000 specimens collected were in the orders Ephemeroptera, Plecoptera and Trichoptera. A total of forty-four families and seventy genera were identifed. Due to the large number of specimens collected and the lack of larval keys at the specific level, identification was to the generic level only. In general each genus was represented by one species but *Ephemerella* may have 5 species and *Rhyacophila* and *Hexatoma* each may have 2 species. The approximate number of species collected was 76. Appendix A lists the taxa and the number of specimens collected per taxa by month.

Figure 11 shows the number of genera of adults collected as compared with the number of genera of larvae. Greater numbers of adults were collected during spring and summer then in late fall and winter. The number of genera of larvae collected decreased from December through May, increased from May to September, and then decreased from September through November.

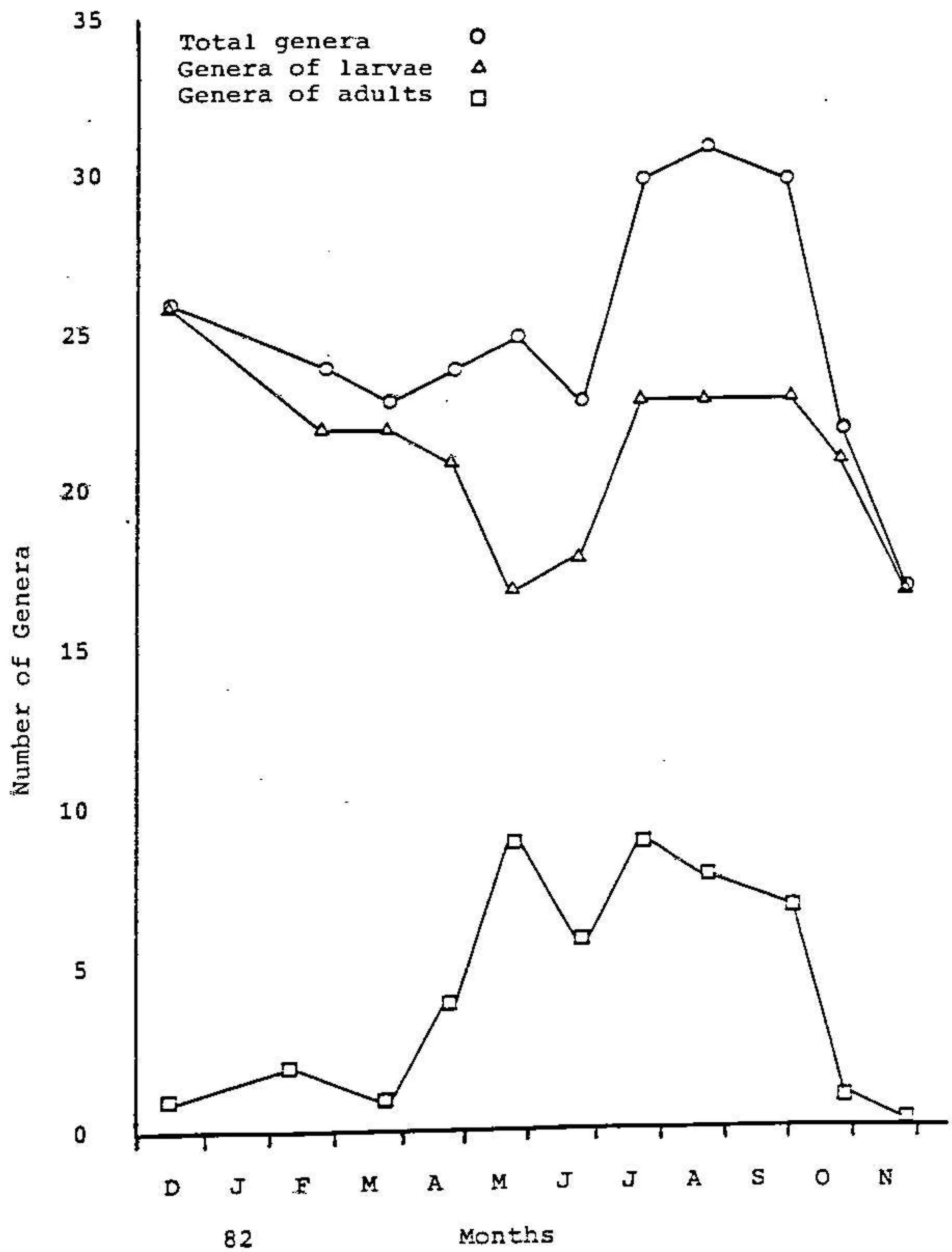

Figure 11. Number of Genera collected per month from Mill Creek, California 1981-1982.

Figure 12 is a comparison of the orders collected at each station. All orders were found at all stations with the exception of Hemiptera being found only at stations C and D.

Two families and eight genera of larval Ephemeroptera were found. Figure 13 is a comparison of the numbers of _Epeorus_ and _Ironodes_ collected. The number of _Epeorus_ larvae collected increased from December through February, remained relatively constant from February through April, and declined to zero from April through September. No larvae were collected from October to December. The number of _Ironodes_ larvae collected increased from December through May, decreased to zero from May through August, increased from September through October, and decreased from November to December. The genera _Ephemerella_, _Cinygmula_, and _Rhithrogena_ had similar patterns as _Epeorus_ while _Baetis_ had a similar pattern as _Ironodes_.

Five families and six genera of Odonata were collected but most were recorded from a single specimen. Only _Cordulegaster_ and _Octogomphus_ were found in any abundance but no adults of these genera were collected. All other adults were collected during the summer months, with _Aeshna_ the most abundant. Many dozens of these were observed during the summer but only one small larva was collected. Very few damselflies were collected either as adults or nymphs.

Plecoptera was represented by eight families and twelve genera with most specimens being larvae. Adults were

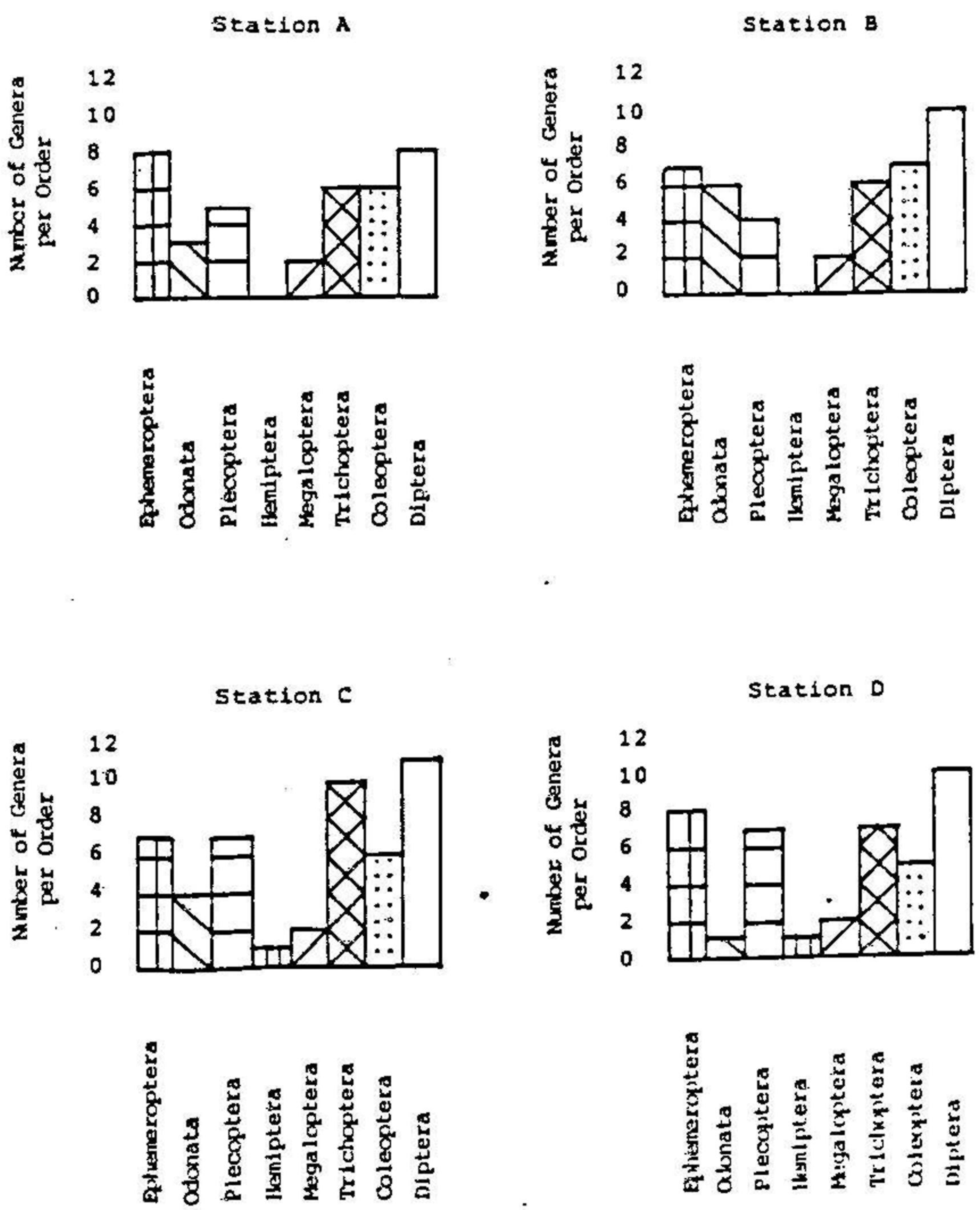

Figure 12. Number of Genera collected per Order from Mill Creek, California, 1981-1982.

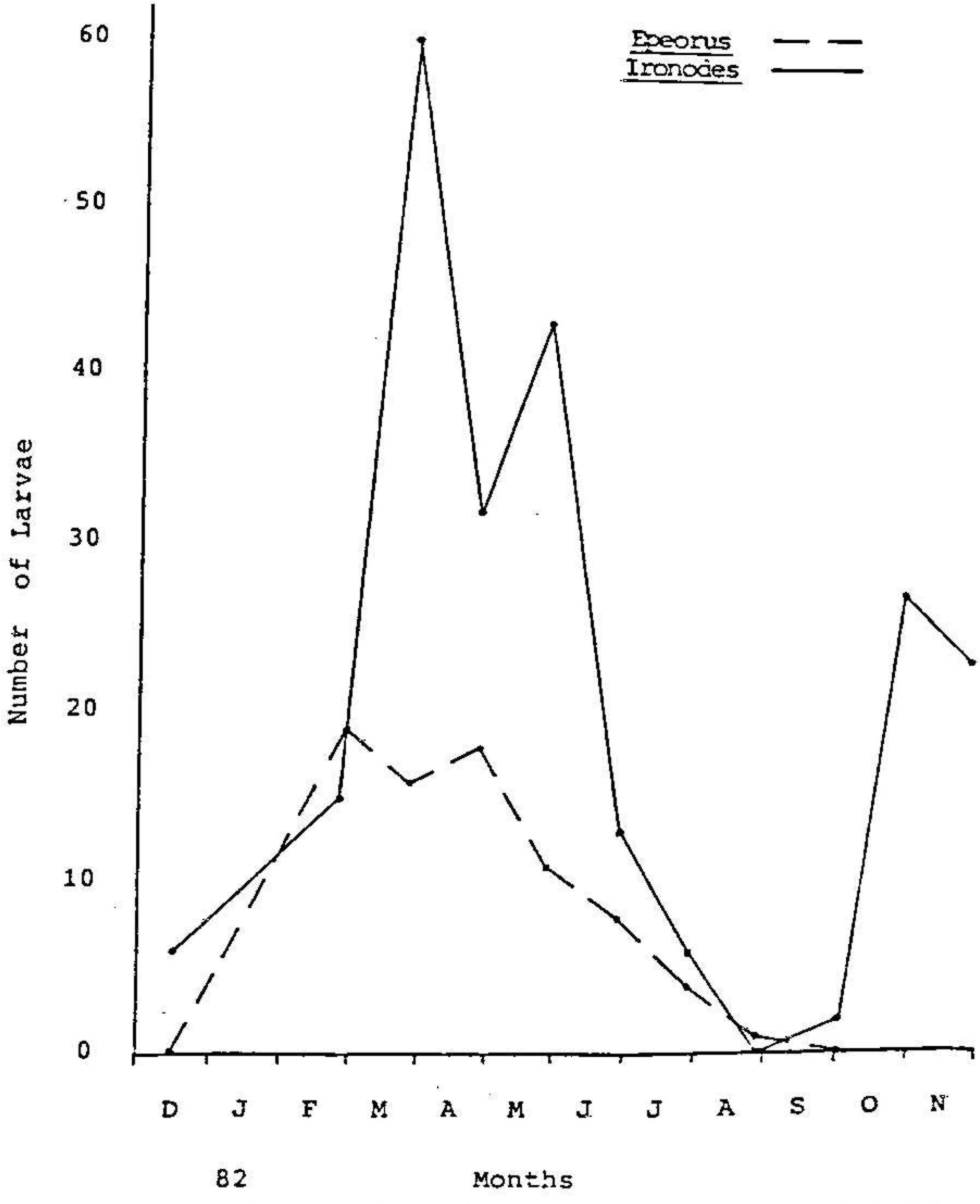

Figure 13. Number of larval Epeorus and Ironodes collected from Mill Creek, California 1981-1982.

collected from four genera; Sweltsa, Mesocapnia and Capnia from October through March and Calineuria in July. Figure 14 is a comparison of the three most commonly collected genera. Calineuria was the most abundant. The number of larvae collected first decreased and later increased from December to April, increased from April through October, and decreased through November. The number of Hesperoperla collected was almost the same for each month with no larvae being collected in February. Hesperoperla and Calineuria were both collected from under cobbles and coarse gravel with Hesperoperla being much less abundant than Calineuria. Pteronarcys was the least abundant of the larval stoneflies collected but was the largest in size. Approximately the same number of larvae were collected each month with none being collected from March through July.

The only hemipterans were adult Gerris collected along the edge of the stream wherever any small, quiet pool of water existed.

Megaloptera was represented by two families and two genera. Sialis was collected infrequently in its larval stage; no adults were collected. Dysmicohermes was collected every month in its larval stage and adults were collected in July.

Eleven families and fourteen genera of Trichoptera were collected. Most of these were represented by scattered collections of adult Anagapetus and Hydroptila, larval

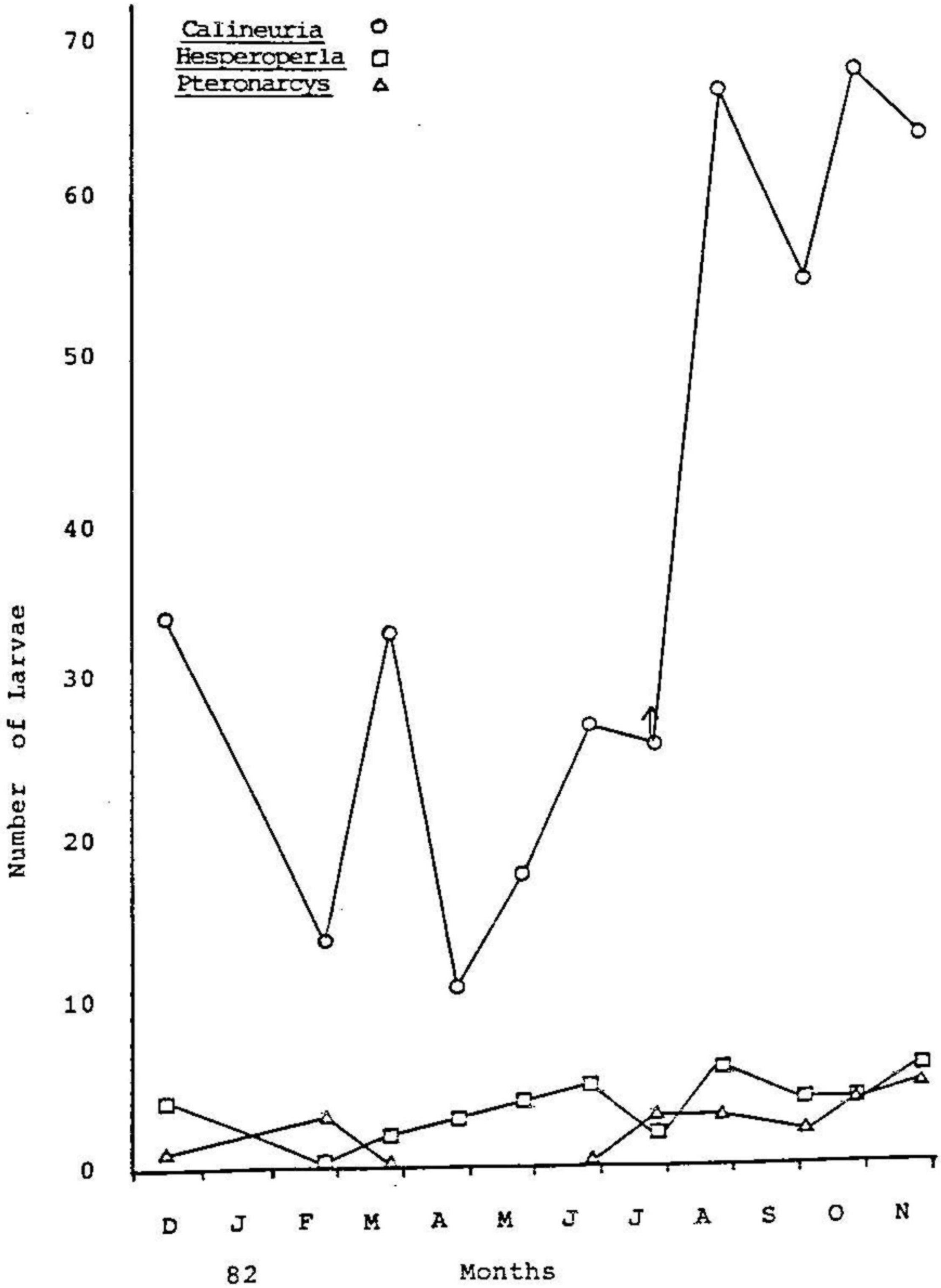

Figure 14. Number of larval Calineuria, Hesperoperla and Pteronarcys collected from Mill Creek, California, 1981-1982.

↑-adults collected in addition to larvae

Heteroplectron, *Parapsyche*, *Dolophilodes*, *Wormaldia*, *Polycentropus* and *Yphria* and both stages of *Agapetus*, *Hydropsyche*, *Lepidostoma*, *Psychoglypha*, *Rhyacophila* and *Gumaga*. Adults were collected from May to October with *Lepidostoma* being the only genus in which adults were collected after August. Figure 15 is a comparison of the three most common genera collected. The number of *Hydropsyche* larvae collected increased from February to May, decreased from may to June, increased from June through September and decreased from October to February. Adults were collected in June and July. The number of *Parapsyche* larvae increased from May to July, remained the same from July through August, and decreased through September. Adults were collected in April. The number of *Rhyacophila* larvae collected increased from December through June with a slight decrease in April, and decreased from June through November. Adults were collected from April through June. Pupae were collected from March through October. *Rhyacophila* was the most abundantly collected and predominant caddisfly of the stream.

Seven families and ten genera of Coleoptera were found. Adults of *Amphizoa*, *Deronectus*, *Hydrovatus* and *Ametor* and larvae of *Agabinus*, *Cleptelmis*, *Lara*, *Eubrianax* and *Anchycteis* along with both stages of *Agabus* were collected. Figure 16 is a comparison of the two most commonly collected genera. The number of *Eubrianax* larvae collected increased from

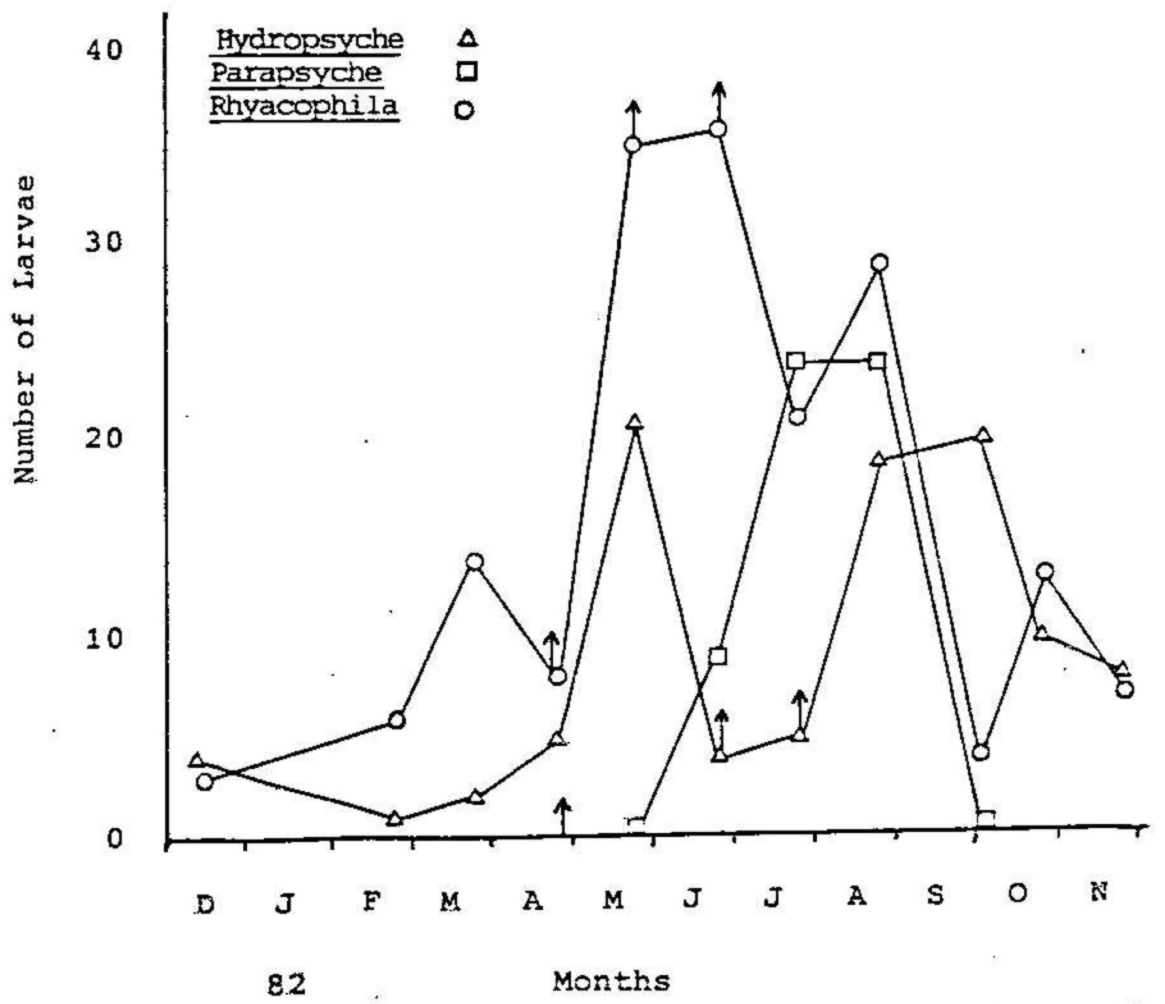

Figure 15. Number of larval Hydropsyche, Parapsyche and Rhyacophila collected from Mill Creek, California, 1981-1982.

↑-adults collected in addition to larvae

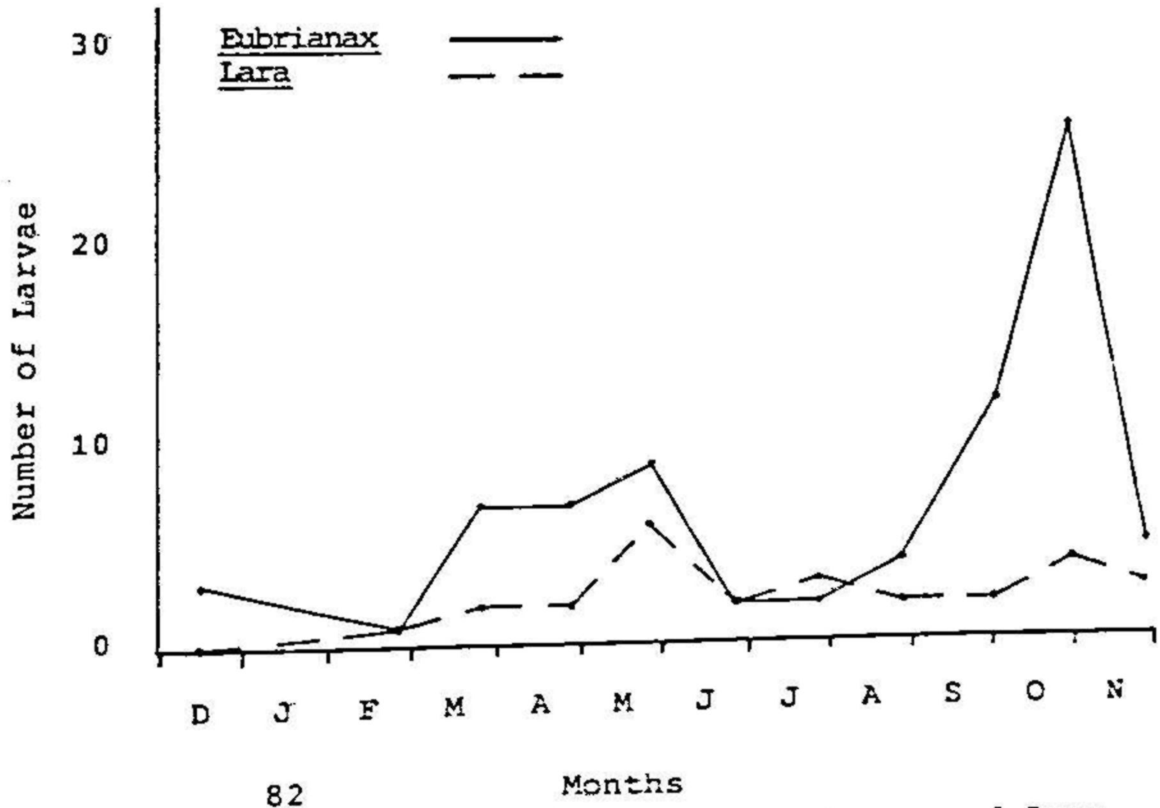

Figure 16. Number of larval *Eubrianax* and *Lara* collected from Mill Creek, California, 1981-1982.

February through May, decreased through June, increased from July through October and decreased from November to February. The number of _Lara_ larvae collected was approximately the same for each month with a slight increase in May.

Diptera was represented by eight families and seventeen genera. Most of these taxa were identified from one or two specimens. _Dixa_, _Prosimulium_, _Simulium_, _Odontomyia_, _Tabanus_, _Dicrantoa_, _Hexatoma_, _Holorusia_ and _Limonia_ were presented by larvae. _Aedes_, _Culex_, _Culiseta_, _Phyllolabis_, _Paratendipes_ and _Pentaneura_ were represented by adults, and _Agathon_ and _Tipula_ were represented by larvae and adults. Figure 17 is a comparison of the two most common genera collected. _Tipula_ is not very abundant but occurred consistently. Adults were collected from May through July. _Hexatoma_ was the most abundant dipteran collected. The number of larvae collected increased from February through October, and decreased from November through February. No adults of _Hexatoma_ were collected. Approximate emergence times were established for seven other genera by adult collections. All adults were collected from May through August. No pupae were collected within the order.

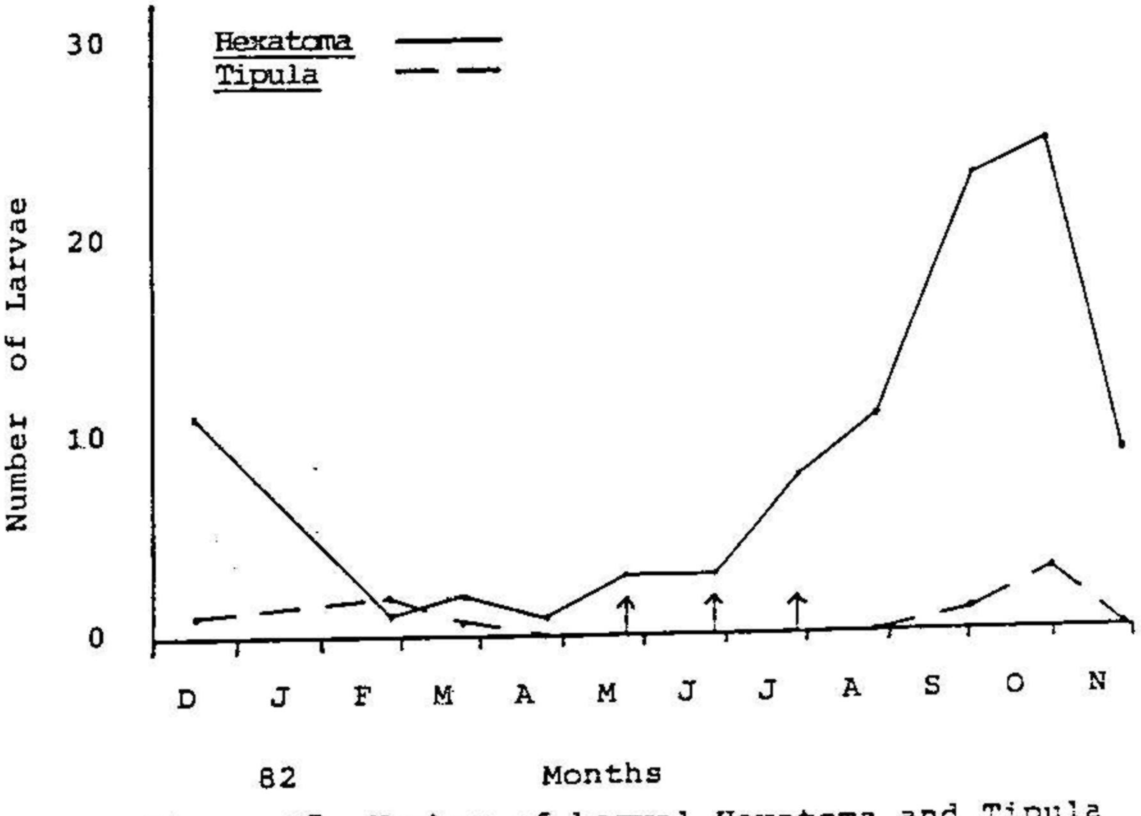

Figure 17. Number of larval <u>Hexatoma</u> and <u>Tipula</u> collected from Mill Creek, California, 1981-1982.
↑- adults collected in addition to larvae

DISCUSSION

Mill Creek possessed most of the characteristics of a typical third-order stream. A geomorphologist would describe a third-order stream as a tributary of a drainage basin that received only first- and second-order streams (Leopold, 1964). Inspection of the U.S. Geologic Survey West Point and Blue Mountain Quadrangle maps indicated that Mill Creek was a third-order stream (Appendix C). Also, the size parameters of Mill Creek (widths 3-8 m) fell within those described by Cummins for a third-order stream (Figure 1).

Terrestrial plants dominated the stream. There was a year round input of coarse particulate matter from the evergreen trees and autumnal input from the deciduous trees. Madrone appeared to play an important role as a supplier of CPOM. Being a broad-leaved evergreen, its leaves were falling throughout the year. These leaves were already partially skeletonized before leaving the tree. Most likely, they were attacked by bacteria or fungi which began to break down the leaves, thus making the nutrients in them more readily available for processing by the shredders of the stream. Also, the microflora attacking the leaves may have been used as nutrients similarly to that reported by Cummins for oak leaves (Cummins, 1974).

Aquatic autotrophs were relatively scarce. Some moss was present along with some filamentous algae. During the warmer months, cobbles and boulders were slippery under foot, indicating some type of algal flora, possibly diatoms.

The fauna was consistent with that expected for a third-order stream. Figure 1 suggests that for a first-to third-order stream approximately forty-five percent of the insects collected should be collectors, thirty-five percent should be shredders, fifteen percent predators and five percent grazers. Using the information from Appendix B, the insect genera from Mill Creek could be classified as follows: thirty-seven percent collectors, twenty-five percent shredders, twenty percent engulfers (predators), and twenty percent grazers. Six genera of grazers collected were mayflies. If one considers these organisms as being omnivorous, eating both as grazers on algal growth as well as collectors of detritus on the rocks, then they can be classified with the collectors (Brittain 1982). This would increase the percentage of collectors and reduce the percentage of grazers; thus the percentage of feeding types becomes even more typical of a third-order stream.

The sediments of the stream bed were also as expected for a third-order stream. They were primarily cobbles with some large boulders, gravel and fine sediment. Stream width varied from three to eight meters, approximating that of a third order stream. Figure 18 provides a more detailed look

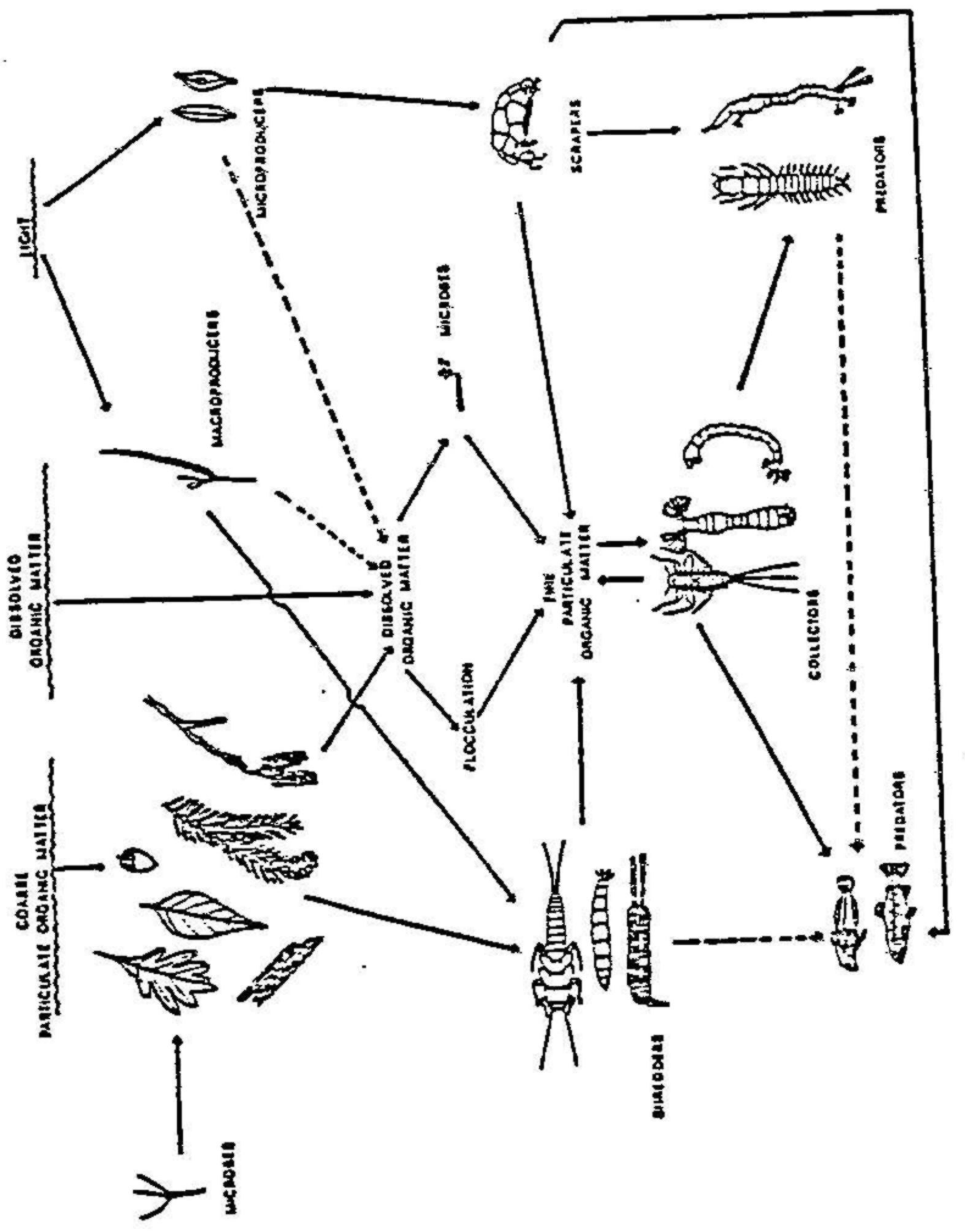

Figure 18. A diagramatic representation of the structure and function in first-to third-order streams (Cummins, 1975).

at the structure and function of a first-to third-order stream.

Collecting stations A through D were chosen in hopes that each site would yield different benthic fauna directly related to identifiable differences at each site. When comparing the number of genera collected per order for each site, the only apparent difference was for Hemiptera. Due to collecting inefficiencies, Gerris was not collected at sites A and B (Figure 12). For all other orders, the stream appears to meet habitat requirements equally at all stations.

Further research, specifically designed to more accurately measure the physical differences and more accurately sample the fauna of each site, might show there are differences in the fauna at each site.

Within the Order Ephemeroptera, univoltine life cycles for Ephemerella, Paraleptophlebia, Cinygmula, Epeorus and Rhithrogena have been reported along with bivoltine cycles for Baetis and Ironodes (Edmunds et al, 1976). Genera with univoltine cycles generally complete adult emergence by late spring and can have synchronized or dispersed emergence pattern (Brittain, 1982). Since no adults were collected in these genera, it is difficult to speculate on the type of emergence pattern. Since most adults have a spring emergence, it seems reasonable to be collecting larvae from midsummer through winter and into spring. Larvae were not collected until winter and this pattern could be explained by two hypotheses: the egg goes through a long development time (or has a diapause) and larvae hatch in the early spring; or there is a short egg development with small larvae developing slowly through the winter (Brittain, 1982). In either case, eggs and young larvae were too small to be trapped by the collecting screen.

Mayflies have been classified as collector/gatherer/ grazer (Merritt and Cummins, 1984) and have mouth parts adapted for these feeding methods (Brittain, 1982). Those of Mill Creek had an increasing winter/spring larval population until emergence in late spring. How did they partition the food resource? Several studies indicate that distribution of aquatic insects is partially due to the nature of the stream's substrate (Brusven and Prather, 1974; deMarch, 1976). With the exception of Baetis, all the mayflies in Mill Creek were poor swimmers having morphological adaptations for clinging or crawling over the substrate.

These adaptations indicate the importance of the substrate for the mayflies of Mill Creek and perhaps enable them to partition the available microhabitats of the stream bottom. According to Cummins (1973) and Brittain (1982) detritus is trapped and algae may grow in these microhabitats. If substrate partitioning did occur among the mayflies of Mill Creek then the food resource would also be partitioned. Baetis and Ironodes were able to produce a second generation throughout the summer probably due to reduced competition from the other genera.

Ephemerella has five morphologically distinct morphs within this collection. Structural features such as an adhesive disc on the venter of the abdomen, dorsal spines from head to ninth abdominal segment, inner tail 5-7 times longer than outer tails, conspicuously developed lateral, abdominal spines, tail banding, and body markings could be used to separate these morphs. Further work is needed to determine if these morphs are different species.

With respect to the odonata, one would not expect to find nymphs in a running stream habitat. Only Cordulegaster and Octogomphus show a preference for loctic waters. They burrow in fine sediment and wait for their prey (Merritt and Cummins, 1984). This most likely explains their greater numbers in the nymphal collection of Mill Creek. These genera have been reported to have life cycles of three to four years duration (Usinger, 1956). The remainder of the odonates collected are classified as climbers, clingers and/or sprawlers which usually live in lentic waters, with Argia listed as living in both aquatic environments (Merritt and Cummins, 1984). This easily explains the collection of adult Aeshna, Brachymesia and Sympetrum with the collection of only one larval Aeshna. Their larvae live in pools, bogs and ponds and the adults come to the open areas adjoining the stream to feed on other insects. Unlike other aquatic insects, these adults are long-lived and are active predators (Merritt and Cummins, 1984).

The plecopterans, Calineuria and Hesperoperla are carnivorous throughout their nymphal development. Adult emergence has been reported to occur from July through August (Fuller and Stewart, 1977; Sheldon, 1969). This raises two important questions. How do the members of these genera avoid inter- and intraspecific competition when partitioning the food resources of the creek? At Sagehen Creek, California, Sheldon (1969) studied the problem of resource partitioning by different sized larvae of Calineuria (= Acroneuria) californica. Sheldon's summary states that "Trichoptera were eaten by large nymphs, Ephemeroptera by those of intermediate size and Diptera by the smallest nymphs." Since all of these prey species were abundant in Mill Creek, it seems reasonable that a similar method of resource partioning was accomplished by Calineuria in this stream. Fuller and Stewart (1977) reported a similar resource partitioning by Hesperoperla pacifica from the Upper Gunnison River in Colorado. First year nymphs primarily fed upon chironomid larvae except in May when they switched to mayfly larvae. Second year nymphs primarily fed upon large caddisfly larvae from autumn through early spring and then shifted back to large chironomid larvae. Again, all of these prey were available in Mill Creek. Thus, both genera had a means of reducing intraspecific competition among the different aged larvae.

Interspecific competition may exist between these two genera. As shown in Figure 14, Calineuria, on the average, is ten times more abundant than Hesperoperla. Why is this true and how can Hesperoperla continue to survive under such heavy pressure from Calineuria? In Fuller and Stewart's (1977) study, a similar situation existed between Hesperoperla pacifica and Classenia sabulosa. They suggested that the larger nymphs were able to avoid competition through dietary preferences. Hesperoperla fed primarily upon caddisflies and avoided eating mayflies while Classenia fed primarily upon mayflies (Fuller and Stewart, 1977). They also showed that the larger nymphs differed in the kinds and amounts of mayflies ingested when both fed upon them. C. sabulosa ate emphemerellids (53%), baetids (25%), and heptageniids (22%) in that preference order while H. pacifica selected more baetids (57%), and less ephemerellids (35%) and heptageniids (8%). Hesperoperla fed primarily upon Diptera and Trichoptera, and large nymphs fed on Ephemeroptera. Calineuria ate Diptera, Trichoptera and Ephemeroptera. This ability to feed upon a wider range of prey may explain Calineuria's greater abundance.

The smaller Hesperoperla nymphs seem to have the most difficult food partitioning problems. They feed almost exclusively upon chironomids throughout the summer and early fall (Fuller and Stewart, 1977). Small nymphs of _Calineuria_ feed primarily upon dipteran larvae, presumably chironomids, in the summer months (Sheldon, 1969). Since there are many more _Calineuria_ nymphs present, _Hesperoperla_ nymphs may switch to feeding upon mayflies as was reported by Fuller and Stewart (1977). If medium-sized nymphs of _Calineuria_ feed primarily upon mayflies (Sheldon, 1969), then any attempt by _Hesperoperla_ to switch to this food may not be a very successful strategy. Intense competition faced by the young nymphs of _Hesperoperla_ may explain its low numbers in Mill Creek. Further study of these two genera could determine how they partition the food resources and what effect this has on the abundance of each.

Kathroperla and _Isoperla_ are considered to be engulfers and collectors (Merritt and Cummins 1984). Most likely they follow the pattern reported by Fuller and Stewart (1977) in which small nymphs eat primarily algae and detritus and larger nymphs switch to eating chironomids and caddisflies. Switching from plant/detritus feeding to carnivory should reduce competition if the switch is made during a time when prey species are abundant. Very few individuals of these genera were collected.

All other genera of stoneflies collected were listed as shredder/detrivore or shredder/collector (Merritt and Cummins, 1984). Of these, only _Pteronarcys_ was collected with any consistancy. Its life cycle is of the multi-year type although it has been reported to be univoltine in the warmer climates of Virginia (Lechleitner and Kondratieff, 1983). This stonefly feeds upon CPOM in the form of large wood particles. Its long life cycle may be due to adopting the same strategies as Lara-a slow metabolic rate with the utilization of enriched food at various times in the cycle (Anderson and Cummins, 1979).

Within the Order Megaloptera, the Corydalidae were represented by the single genus Dysmicohermes. It has been reported to have life cycles from two to five years (Usinger, 1956). These larvae are the largest predators in the stream and this may accunt for the relatively small numbers collected. Very few specimens of Sialis were collected. Although this genus is widespread throughout N. America, the larvae generally require a substrate that is soft with abundant detritus (Merritt and Cummins, 1984). The substrate of Mill Creek was not of this type, possibly explaining the low numbers of Sialis collected.

The trichopterans, Hydropsyche, Parapsyche, Wormaldia and Dolophilodes are reported to be collector/filterers (Merritt and Cummins, 1984). They obtain food by spinning capture nets of varying mesh sizes. Dolophilodes and Wormaldia have been reported to have capture nets of much smaller size than both Hydropsyche and Parapsyche (Malas and Wallace, 1977). These different sized nets provide a mechanism for the partitioning of food resources among these genera. Dolophilodes and Wormaldia can feed upon very small detritus which would pass through the larger nets of Hydropsyche and Parapsyche. Figure 15 may provide some insight as to how genera with similar sized mesh in the capture nets partition the food resource. From May through July the number of Hydropsyche larvae decreased dramatically, probably due to adult emergence. At the same time, the number of Parapsyche larvae was increasing dramatically. This temporal separation would allow both genera to occupy the same location. This kind of growth pattern has been reported among most stream macro-invertebrates (Cummins and Klug, 1979). Wormaldia and Dolophilodes also displayed the same type of growth pattern. Wormaldia larvae were abundant from June through August while Dolophilodes larvae were abundant from August through October.

There appear to be two distinct morphs of Rhyacophila inhabiting Mill Creek. One has gill tufts along the abdominal segments and the other lacks these gill tufts. Very little information was given in the keys about the tufted morph making its identification difficult. Rearing studies might establish the presence of two species and add needed information about the tufted morph.

A number of genera in my collection were represented by only a few specimens. Some possible explanations for this follow. Heteroplectron, Yphria, and Lepidostoma larvae prefer pools, slow currents and stream margins as habitats

(Wiggins, 1978). Few collections were done in these habitats in Mill Creek. The larvae of <u>Agapetus</u> and <u>Anagapetus</u> specialize in grazing upon diatoms, green algae and fine organic particles on the uppermost, exposed surfaces of rocks while <u>Hydroptila</u> feeds upon filamentous algae by piercing the cells of the filament (Wiggins, 1978). Since these types of food items were uncommon in Mill Creek, it is not surprising that low numbers of these genera were collected.

<u>Lara</u> and <u>Eubianx</u> were the most abundantly collected genera of Coleoptera and were represented only by larvae. <u>Lara</u> has a multi-year life cycle (Anderson and Cummins, 1979) which is related to its diet. It eats water-logged wood, chewing the surface and gouging out the inner layers. Since wood has the lowest nutritional value of any CPOM found in a stream, insects that feed upon it must have a long life cycle with a slow metabolism and some supplemental feeding on higher quality food (Anderson and Cummins, 1979). Water-logged wood was common in Mill Creek particularly at station D.

<u>Eubrianx</u> is considered to be a grazer feeding upon periphyton growing upon the rocks that it clings to (Merritt and Cummins, 1984). The adult stage is very short lived (Merritt and Cummins, 1984) probably explaining the absence of adults in the collection.

Of the remaining beetles collected, most were predators. Dytiscidae, commonly called the predacious diving beetles, was represented by four genera. Both larvae and adults are active predators that pursue prey by diving down into the stream (Merritt and Cummins, 1984). The Amphizoidae, commonly called the trout stream beetles, were represented by the genus *Amphizoa*. Adults do not live directly in the water but are found crawling among debris just above the water's surface. They are primarily predators upon stonefly larvae and crawl into the stream to capture them. They then return to the surface to devour their prey (Merritt and Cummins, 1984). Few debris dams existed in Mill Creek and this may explain the low numbers of *Amphizoa* collected.

The Order Diptera was most abundantly represented by the Tipulidae. *Hexatoma* had two morphologically distinct forms within this collection. One of these had a very swollen seventh abdominal segment and was collected every month. The other had prolegs on the venter of the abdominal segments and was collected from late summer through early winter. Additional work needs to be done to determine if two species are present and to determine if temporal separation is being used as a mechanism to reduce competition for food.

Only adults of *Phyllolabis* were collected. This genus is of particular interest because identification is possible only with the adults. The larvae are not included in the identification keys. Rearing of this genus could be of major taxonomic importance.

The family Chironomidae was represented by three genera. Approximately eighty larvae were collected throughout the summer and early fall. Due to the special techniques involved and the small size of the larvae, identification was not attempted. This family was cited throughout the literature as being an important food source for many predatory insect groups. Twenty percent of all genera identified in this study were predators. The ecological associations between these predators and the chironomids need to be established. The family Culicidae was represented by three genera, all collected as adults. These are more characterisitc of ponds and pools (Merritt and Cummins, 1984). These specimens probably completed their life cycles in the few shallow pools or marshy areas along the edge of Mill Creek. This would explain the absence of larvae in the collection and the presence of lentic organisms in a lotic environment.

Every research project usually raises more questions and suggests more projects. I would like to include some of these at this point.

Collection and identification of adults for all the Mill Creek insects is a must.

Rearing studies should be done to identify all larvae to species. Once species identification was completed, life histories could be established, growth rate studies could be done and energy transfer among the community members worked out.

The physical parameters of the creek need to be measured and attempts made to explain their effects on the species. What role do these parameters assume in shaping this community?

What is the relevant role of each of the plant groups that dominate Mill Creek? Is the energy input from one group more important than another? Twenty percent of the insects collected were classified as grazers. Presumably, these fed upon algae such as diatoms. Identification of these algae is needed and their relative contribution to the amount of energy they input into the creek needs to be determined.

SUMMARY

The insect fauna collected from Mill Creek was typical for a first- to third-order stream. Approximately forty percent of the genera identified were classified as collectors and twenty-five percent as shredders. These percentages reasonably approximate Cummins' predictions for a shredder/collector system (Figure 1). Mill Creek was dominated by its land plants as predicted for a first to third order streeam. Large debris--leaves, needles, bark, twigs and cones--fell year-round and few autotrophs were noted growing in the creek. Sediments and size of stream bed proved to be consistent with expectations for a third order stream.

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Appendix A: The Number of Taxa Collected per Month from Mill Creek, California, 1981-1982.

TAXA	MONTHS										
	12	2	3	4	5	6	7	8	10/2	10/31	11
Order Ephemeroptera Family Baetidae											
Genus *Baetis*	3	7	10	4	18		1	1	4	14	3
Ameletus	1			2	6				5		
Ephemerella	1	16	16	8	51	26	3	2	1	1	1
Paraleptophlebia	10	1		2							1
Family Heptageniidae											
Genus *Cinygmula*		1	3	4	3						
Epeorus		19	16	18	11	8	4	1			
Ironodes	6	15	60	32	43	13	.6		2	27	23
Rithrogena	2	5	5	7							
Order Odanata Family Aeshnidae											
Genus *Aeshna*		1						3*			
Family Coenagrionidae											
Genus *Argia*	1		2								
"X"								1			
Family Cordulegastridae											
Genus *Cordulegaster*	3	1	1		1		1	3	3	2	2
Family Gomphidae											
Genus *Octogomphus*					1		1	1	1	1	
Family Libellulidae											
Genus *Brachymesia*							1*				
Tarnetrum								1*			
Order Plecoptera Family Chloroperlidae											
Genus *Kathroperla*				1							
Sweltsa									1*		
Suwallia complex				2					1		

Appendix A: (continued)

TAXA	MONTHS										
	12	2	3	4	5	6	7	8	10/2	10/31	11
Family Capniidae											
Genus <u>Capnia</u>			1*								
<u>Mesocapnia</u>	1 1*										
Family Leuctridae											
Genus <u>Paraleuctra</u>					1						
Family Nemouridae											
Genus <u>Malenka</u>									1		3
<u>Zapada</u>			2								
Family Perlidae											
Genus <u>Calineuria</u>	34	14	33	11	18	27	26 2*	67	55	68	64
<u>Hesperoperla</u>	4		2	3	4	5	2	6	4	4	6
Family Perlodidae											
Genus <u>Isoperla</u>		2	1								1
Family Pteronarcidae											
Genus <u>Pteronarcys</u>	1	3					3	3	2	4	5
Family Taeniopterygidae Genus <u>Taenionema</u>		5									
Order Hemiptera Family Gerridae											
Genus <u>Gerris</u>					6*		4*	2*	3*		
Order Megaloptera Family Corydalidae											
Genus <u>Dysmicohermes</u>	4	1	3	1	4	4	3 2*	5	2	5	3
Family Sialidae											
Genus <u>Sialis</u>	3					1				2	
Order Trichoptera Family Calamoceratidae											
Genus <u>Heteroplectron</u>	1										

Appendix A: (continued)

TAXA	MONTHS										
	12	2	3	4	5	6	7	8	10/2	10/31	11
Family Glossomatidae											
Genus <u>Agapetus</u>						1*	1*	1			
<u>Anagapetus</u>					1*						
Family Hydropsychidae											
Genus <u>Hydropsyche</u>	4	1	2	5	21	4 1*	5 1*	19	20	10	8
<u>Parapsyche</u>				1*	9	26	26				
Family Hydroptilidae											
Genus <u>Hydroptila</u>				1*							
Family Lepidostomatidae											
Genus <u>Lepidostoma</u>	3								1*		
Family Limnephilidae											
Genus <u>Psychoglypha</u>				1*			3				
Family Philopotamidae											
Genus <u>Dolophilodes</u>								32	11	2	
<u>Wormaldia</u>						1	6	11			
Family Polycentropodidae											
Genus <u>Polycentropus</u>						1					
Family Phryganeidae											
Genus <u>Yphria</u>	1										
Family Rhyacophilidae											
Genus <u>Rhyacophila</u>	3	6	14 3!	8 2*	35 1! 2*	36 9! 2*	21 6!	29 11!	4 1!	13	7
Family Sericostomatidae											
Genus <u>Gumaga</u>				2			2 1*		2	3	4
Order Coleoptera Family Amphizoidae											
Genus <u>Amphizoa</u>							1*		1*		

Appendix A: (continued)

TAXA	MONTHS										
	12	2	3	4	5	6	7	8	10/2	10/31	11
Family Dytiscidae											
Genus *Agabinus*								1			
Agabus	1	1*					1*	7*	2*		
Deronectus				4*	7*	1*	1*	4*	6*	3*	
Hydrovatus									1*		
Family Elmidae											
Genus *Cleptelmis*								1			
Lara		1	2	2	6	2	3	2	2	4	3
Family Hydrophilidae											
Genus *Ametor*		1*			1*						
Family Lampyridae											
Genus "Y"				1							
Family Psephenidae											
Genus *Eubrianax*	3	1	7	7	9	2	2	4	12	26	5
Family Ptilodactylidae											
Genus *Anchycteis*							1				
Order Diptera Family Blephariceridae											
Genus *Agathon*		1		2	2*						
Family Chironomidae											
Genus *Paratendipes*						4*					
Pentaneura						4*					
"Z"	1					17	16	27	24		
Family Culicidae											
Genus *Aedes*					1*						
Culex								1*			
Culiseta								1*			
Family Dixidae											
Genus *Dixa*						1	1		1		

Appendix A: (continued)

TAXA	MONTHS										
	12	2	3	4	5	6	7	8	10/2	10/31	11
Family Simulidae											
Genus *Prosimulium*		4	1								
Simulium						5	3			1	
Family Stratiomyidae											
Genus *Odontomyia*								1			
Family Tabanidae											
Genus *Tabanus*	1		1							1	
Family Tipulidae											
Genus *Dicranota*								3	1	7	
Hexatoma	11	1	2	1	3	3	8	11	22	18	9
Holorusia	3	1									
Limonia	1										
Phyllolabis					3*						
Tipula	1	2	1		6*	6*	6*		1	3	
Total Larval Taxa	27	22	22	21	17	18	23	23	23	21	17
Total Adult Taxa	1	2	1	4	9	6	9	8	7	1	0
Total Taxa	27	24	23	24	25	23	30	31	30	22	17

* - number of adults collected
! - number of pupae collected
all other numbers - number of larvae collected

Appendix B: General Information About the Aquatic Insects of Mill Creek, California

Taxa	Stations Collected				Relative Numbers Collected				Life Stages Collected		Habitat !		Trophic ! Relationships	Habit!
	A	B	C	D	A*	C*	F*	R*	L+	A+	Lotic	Lentic		
Order Ephemeroptera														
<u>Baetis</u>	x	x	x	x		x			x		x		collectors,scrapers gatherers	swimmers,climbers clingers
<u>Ameletus</u>	x	x	x	x			x		x		x		collectors	swimmers,clingers
<u>Ephemerella</u>	x	x	x	x		x			x		x		collectors,scrapers shredders(herbivore)	swimmers,clingers sprawlers
<u>Paraleptophlebia</u>	x		x	x			x				x		collectors,gatherers shredders(detrivore)	swimmers,clingers
<u>Cinygmula</u>	x	x	x	x				x	x		x		collectors,scrapers	clingers
<u>Epeorus</u>	x	x	x	x		x			x		x		collectors,scrapers	clingers
<u>Ironodes</u>	x	x	x	x			x		x		x		collectors,scrapers gatherers	clingers
<u>Rhithrogena</u>	x	x		x			x		x		x		collectors,scrapers gatherers	clingers
Order Odonata														
<u>Aeshna</u>		x	x					x	x	x		x	engulfers	climbers
<u>Argia</u>	x		x					x	x		x		engulfers	clingers,climbers
"X"		x						x		x	x		engulfers	climbers
<u>Cordulegaster</u>	x	x	x	x			x		x		x		engulfers	burrowers
<u>Octogomphus</u>	x	x	x					x	x		x		engulfers	burrowers
<u>Brachymesia</u>		x						x		x		x	engulfers	sprawlers
<u>Sympetrum</u>		x						x		x		x	engulfers	climbers,sprawlers
Order Plecoptera														
<u>Kathroperla</u>	x							x	x		x		engulfers,collectors	clingers
<u>Sweltsa</u>			x					x	x		x		collectors,scrapers	clingers
<u>Suwallia</u> complex		x		x				x	x		x		collectors,engulfers	clingers
<u>Capnia</u>			x					x	x	x	x		shredders(detrivore)	clingers,sprawlers
<u>Mesocapnia</u>			x					x	x	x	x		shredders(detrivore)	clingers,sprawlers
<u>Paraleuctra</u>				x				x	x		x		shredders(detrivore)	clingers,sprawlers
<u>Malenka</u>	x			x				x	x		x		collectors,shredders	clingers,sprawlers
<u>Zapada</u>			x					x	x		x		shredders(detrivore)	clingers,sprawlers

Appendix B: (continued)

Taxa	Stations Collected				Relative Numbers Collected				Life Stages Collected		Habitat !		Trophic ! Relationships	Habit!
	A	B	C	D	A*	C*	F*	R*	L+	A+	Lotic	Lentic		
Calineuria	x	x	x	x	x				x	x	x		engulfers	clingers
Hesperoperla	x	x	x	x			x		x		x		engulfers	clingers
Isoperla				x				x	x		x		collectors,engulfers	clingers,sprawlers
Pteronarcys	x		x	x			x		x		x		shredders(detrivore) scrapers	clingers,sprawlers
Taenionema		x						x	x		x		scrapers	clingers,sprawlers
Order Hemiptera														
Gerris			x	x			x			x	x	x	piercers(carnivore)	skaters
Order Megaloptera														
Dysmicohermes	x	x	x	x			x		x	x	x		engulfers	clingers,climbers
Sialis	x	x	x	x				x	x		x	x	engulfers	clingers,climbers burrowers
Order Trichoptera														
Heteroplectron			x					x	x		x		shredders(detrivore)	sprawlers-case
Agapetus	x	x		x				x	x	x	x		collectors,scrapers	clingers-case
Anagapetus				x				x		x		x	scrapers	clingers-case
Hydropsyche	x	x	x	x		x			x	x	x	x	collectors(filterer)	clingers-net spinn
Parapsyche	x	x	x	x		x			x		x		collectors(filterer)	clingers-net spinn
Hydroptila			x					x		x	x		piercers(herbivore) scrapers	clingers-case
Lepidostoma			x					x	x	x	x		shredders(detrivore)	climbers,sprawlers clingers-case
Psychoglypha			x					x	x	x	x		collectors,shredders	sprawlers,clingers-case
Dolophilodes	x	x	x	x			x		x		x		collectors(filterer)	clingers-silk net
Wormaldia	x	x	x	x			x		x		x		collectors(filterer)	clingers-silk net
Polycentropus			x					x	x		x	x	collectors,engulfers	clingers-silk tube
Yphria	x							x	x		x		engulfers	sprawlers,clingers-case
Rhyacophila	x	x	x	x	x				x	x	x		collectors,shredders engulfers	clingers-free rang
Gumaga		x	x	x			x		x	x	x		shredders	sprawlers-case

Appendix B : (continued)

Taxa	Stations Collected				Relative Numbers Collected				Life Stages Collected		Habitat !		Trophic ! Relationships	Habit!
	A	B	C	D	A*	C*	F*	R*	L+	A+	Lotic	Lentic		
Order Coleoptera														
<u>Amphizoa</u>			x					x		x	x		engulfers	clingers
<u>Agabinus</u>				x				x	x		x	x	piercers(carnivore)	swimmers,divers
<u>Agabus</u>	x	x	x	x			x		x	x	x	x	piercers(carnivore)	swimmers,divers
<u>Deronectus</u>	x	x	x	x			x			x	x	x	piercers(carnivore)	swimmers,climbers
<u>Hydrovatus</u>		x						x		x	x		piercers(carnivore)	no information
<u>Cleptelmis</u>	x							x	x		x		collectors,scrapers	clingers
<u>Lara</u>	x	x	x	x			x		x		x		shredders(detrivore)	clingers,burrowers
<u>Ametor</u>	x		x					x		x	x	x	collectors	clingers
"Y"		x						x	x	x			no information	no information
<u>Eubrianax</u>	x	x	x	x		x			x		x		scrapers	clingers
<u>Anchycteis</u>		x						x	x		x		shredders(herbivore)	burrowers
Order Diptera														
<u>Agathon</u>	x	x						x	x	x	x		scrapers	clingers
<u>Paratendipes</u>				x				x		x	x		collectors,gatherers	burrowers(tube builder)
<u>Pentaneura</u>				x				x		x	x		predators,collectors	sprawlers
"Z"	x	x	x	x		x			x		x	x	predators,scrapers, collectors,shredders, gatherers	clingers,sprawlers, burrowers
<u>Aedes</u>			x					x		x		x	collectors,filterers	swimmers
<u>Culex</u>				x				x		x		x	collectors,filterers	swimmers,planktonic
<u>Culiseta</u>				x				x		x		x	collectors,filterers	swimmers,planktonic
<u>Dixa</u>	x	x	x					x	x		x		collectors	swimmers,climbers
<u>Prosimulium</u>	x		x				x		x		x		collectors,filterers	clingers
<u>Simulium</u>	x	x	x	x			x		x		x	x	collectors,filterers	clingers
<u>Odontomyia</u>			x					x	x			x	collectors	sprawlers
<u>Tabanus</u>			x	x				x	x		x	x	piercers(predator)	sprawlers,burrowers
<u>Dicranota</u>	x	x	x	x				x	x		x	x	engulfers	sprawlers,burrowers
<u>Hexatoma</u>	x	x	x	x		x			x		x	x	engulfers	clingers,burrowers

Appendix B : (continued)

Taxa	Stations Collected				Relative Numbers Collected				Life Stages Collected		Habitat !		Trophic Relationships !	Habit!
	A	B	C	D	A*	C*	F*	R*	L+	A+	Lotic	Lentic		
Holorusia	x	x	x	x				x	x		x	x	shredders(detrivore)	burrowers
Limonia	x							x	x		x	x	shredders(herbivore)	burrowers
Phyllolabis			x					x		x			no information	no information
Tipula		x	x	x			x		x	x	x	x	collectors,shredders	burrowers

A* - abundant (10 or more specimens collected per month)
C* - common (5-10 specimens collected per month)
F* - few (1-4 specimens collected per month)
R* - rare (less than 1 specimen collected per month)
L+ - larva
A+ - adult
! - Merritt and Cummins, 1984